Equations governing our 2 months at the Darpa Innovation House

Spiking Retina —STDP—> Leaky Integrate-and-Fire Neuron with Lateral Inhibition

Gar Kenyon *Keni Patel*
Gerd Kunde *Dylan Paiton*
Pete Schultz *Sheng Lundquist*

Average spike count over interval τ:

$$n_i^{\mathcal{T}}(t+\Delta t) = e^{\frac{-\Delta t}{\tau}}\left[A_i(t) + n_i^{\mathcal{T}}(t)\right] \tag{1}$$

Average firing rate over interval τ:

$$f_i^{\mathcal{T}}(t) = \frac{n_i^{\mathcal{T}}(t)}{\tau} \tag{2}$$

Feed-forward excitatory weight adaptation (STDP):
Pre before post is $'$, pre after post is $''$

$$Q_{ij}(t+\Delta t) = Q_{ij}(t) + \beta\left(\frac{\Delta t}{\tau_{oja}}\right)^2 \{Oja * LTP - LTD\}$$

i.e.

$$\begin{aligned} Q_{ij}(t+\Delta t) = Q_{ij}(t) + \beta\left(\frac{\Delta t}{\tau_{oja}}\right)^2 \{ \\ n_{Y_j}^{\tau\,oja}(t)\left[n_{X_i}^{\tau\,oja}(t) - \frac{Q_{ij}(t)}{W_{scale}} n_{Y_j}^{\tau\,oja}(t)\right] \cdot \lambda^{'} A_Y(t) n_{X_i}^{\tau^{'}}(t) \\ -\lambda_j^{''} A_{Xi}(t) n_{Y_j}^{\tau^{''}}(t)\,\} \end{aligned} \tag{3}$$

Feed-forward inhibitory weight adaptation (STDP):
Pre before post is $'$, pre after post is $''$

$$Q_{ij}(t+\Delta t) = Q_{ij}(t) + \beta\{PreAfterPost('') - PreBeforePost(')\}$$

i.e.

$$\begin{aligned} Q_{ij}(t+\Delta t) = Q_{ij}(t) + \beta\{ \\ \lambda_j^{''} A_{Xi}(t) n_{Y_j}^{\tau^{''}}(t) \\ -\lambda^{'} A_Y(t) n_{X_i}^{\tau^{'}}(t)\,\} \end{aligned} \tag{4}$$

Adaptive λ_D for feed-forward weights

$$\lambda_j^D = \lambda_j^{''}$$

$$\lambda_j^D(t+\Delta t) = \lambda_j^D(t) + \frac{\Delta t}{\tau^{thr}}\left[f_j^{\tau^o}(t) - f_o\right]\frac{\lambda^{Dscale}}{f_o} \tag{5}$$

where

$$\lambda_j^D > 0$$

$$\lambda_j^D(0) = \lambda^{Dinit}$$

Lateral inhibition:

$$w_{jk}(t+\Delta t) = w_{jk}(t) + \frac{\Delta t}{\tau_{inh}}\left[f_j^{\tau^{int}}(t) f_k^{\tau^{int}}(t) - f_o^2\right]\frac{1}{f_o^2} \tag{6}$$

Current scales for τ values

$$\begin{aligned}
\tau_{oja} &\approx 50 - 200ms \\
\tau_P &\approx 0 - 10ms \\
\tau_D &\approx 20 - 40ms \\
\tau_{int} &\approx \tau_{oja} \\
\tau_o &= 300 \\
\tau_{thr} &\gg \tau_o \\
\tau_{inh} &\gg \tau_{int}
\end{aligned} \tag{7}$$

Current values for constants:

$$\begin{aligned}
\lambda_P &\approx 1 \\
\lambda_{Dscale} &\approx \lambda_P \\
\lambda_{Dinit} &\approx 1 \\
\beta &= 2 \\
\alpha_{dec} &= 0
\end{aligned}$$